

IMPACT OF DIFFERENCES IN THE SOLAR IRRADIANCE SPECTRUM ON SURFACE REFLECTANCE RETRIEVAL WITH DIFFERENT RADIATIVE TRANSFER CODES

K. Staenz¹, D.J. Williams², G. Fedosejevs¹, and P.M. Teillet¹

¹Canada Centre for Remote Sensing
588 Booth Street, Ottawa, Ontario, Canada K1A 0Y7

²MacDonald Dettwiler and Associates Ltd.
13800 Commerce Parkway, Richmond, British Columbia, Canada V6V 2J3

1. INTRODUCTION

Surface reflectance retrieval from imaging spectrometer data as acquired with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) has become important for quantitative analysis. In order to calculate surface reflectance from remotely measured radiance, radiative transfer codes such as 5S (Tanré et al., 1990) and MODTRAN2 (Berk et al., 1989) play an increasing role for removal of scattering and absorption effects of the atmosphere. Accurate knowledge of the exo-atmospheric solar irradiance (E_0) spectrum at the spectral resolution of the sensor is important for this purpose. The present study investigates the impact of differences in the solar irradiance function, as implemented in a modified version of 5S (M5S) (Teillet and Santer, 1991), 6S (Vermote et al., 1994), and MODTRAN2 (Berk et al., 1989), and as proposed by Green and Gao (1993), on the surface reflectance retrieved from AVIRIS data. Reflectance measured in situ is used as a basis of comparison.

2. DATA USED

An asphalt site within an AVIRIS scene acquired over the Greater Victoria Watershed near Victoria, British Columbia on August 29, 1993 was selected for this study. The extracted AVIRIS radiance spectrum was averaged over the target of 2×3 pixels, which excludes edge pixels. Corresponding ground-based reflectance data were acquired with a GER MARK V spectroradiometer and a Spectralon panel. These data are accurate to within $\pm 5\%$ reflectance. Solar attenuation measurements were collected on the ground at the time of the AVIRIS overflight with a SONOTEK sunphotometer for the calculation of atmospheric optical depths. In addition, estimated water vapour concentrations as reported by Staenz et al. (1994) for this particular AVIRIS dataset were used for atmospheric modelling.

Several E_0 data sets were included in this study (Table 1). These E_0 spectra are based on Iqbal (1983) for the M5S code, Neckel and Labs (1984) for 6S, and a combination of Neckel and Labs, Wehrli (1985), and Thekeakera (1974) for MODTRAN2. The proposed update of the E_0 function in MODTRAN2 suggested by Green and Gao (1993) was also included. This E_0 spectrum is based on Neckel and Labs (1984) and data provided by the ATMOS sensor onboard the Space Shuttle.

3. ANALYSIS AND RESULTS

Three radiative transfer codes, M5S, 6S and MODTRAN2, were used in combination with each of the four aforementioned E_0 functions to generate a total of 12 computed surface reflectances for the asphalt site. The procedure was carried out in three steps. First, the radiative transfer codes were used to generate tables of simulated AVIRIS radiance spectra. Then, the tables were scaled by the spectral ratio of the E_0 function under study to that which is implemented in the radiative transfer code (both convolved to the AVIRIS bandset). Finally, multiplicative and additive coefficients for atmospheric correction were computed

from the tables and applied to the airborne radiances (Williams et al., 1992).

The E_0 functions are plotted for the AVIRIS bands in Figure 1. Variations of up to 20% occur between the different data sets, although the differences are generally within $\pm 5\%$. The main differences are found in the 2100 - 2500 nm region and other notable discrepancies are apparent around 940 nm, 1300 nm, 1650 nm, and 1900 nm. The 6S E_0 function follows the Green and Gao function very closely with the exception of the 1300 nm region. A similar trend can generally be seen for the M5S and the MODTRAN2 E_0 spectra above 800 nm, although deviations from this tendency occur for some of the AVIRIS bands above 1800 nm.

These deviations between the E_0 functions translated to similar relative differences in the retrieved surface reflectances for each of the radiative transfer codes used. Figure 2 shows the reflectances obtained with the MODTRAN2 code. Figure 3 is a blow-up of the 2050 - 2450 nm region of Figure 2. The reflectance spectra generated with the 6S and Green and Gao E_0 functions are slightly smoother in this wavelength region than those produced with the original MODTRAN2 or M5S E_0 datasets. However, none of the retrieved reflectances exactly matches the ground-based spectrum. This is also true for the 940 nm, 1300 nm, and 1600 nm regions (Figure 2), although a closer match with ground-based reflectances is apparent in the last two regions for the reflectances generated with the 6S/Green and Gao E_0 functions.

Changes in the overall shape of the surface reflectance spectra due to the different E_0 functions (Figure 3) are less than those generated by the various radiative transfer codes using the same E_0 dataset (Figure 4). Differences arising from the use of different radiative transfer codes occur especially in the wavelength regions affected by atmospheric gases. For example, Figure 4 shows major reflectance differences above 2250 nm between M5S and 6S/MODTRAN2 generated spectra, even though the E_0 function used (Green and Gao) was the same in each case. This is mainly due to the different methods used for calculation of the atmospheric transmission in these codes (Staenz et al., 1994).

4. CONCLUSIONS

Differences in the E_0 spectra as implemented in M5S, 6S and MODTRAN2 radiative transfer codes and as proposed by Green and Gao can translate to relative differences in retrieved surface reflectance of up to 20%, although they are generally within $\pm 5\%$ at most wavelengths. The largest deviations are found above 2100 nm. In addition, notable differences occur in the 940 nm, 1300 nm, and 1650 nm regions. The overall shape of the retrieved reflectance spectrum is generally less affected by differences between E_0 functions than by differences between the atmospheric radiative transfer codes.

5. ACKNOWLEDGEMENTS

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Table 1: Exo-atmospheric solar irradiance functions (E_0) and their spectral resolution for the AVIRIS wavelength coverage (400-2500 nm) with respect to different radiative transfer codes.

Source	Radiative Transfer Code (spectral resolution)	Spectral Resolution of E_0 Function	
		original	as implemented in radiative transfer code
Iqbal	M5S (5 nm, 20 cm^{-1})	5-100 nm ¹	5 nm
Neckel and Labs	6S (2.5 nm)	1-5 nm ²	5 nm
Neckel and Labs, Wehrli, Thekeakera	MODTRAN2 (variable, finest = 1 cm^{-1})	1-5 nm ² 1-10 nm ³ 5- 100 nm ¹	20 cm^{-1}
Green and Gao	proposed for MODTRAN	2.5 nm	-----

¹ 5nm (400-610nm), 10 nm (610-1000 nm), 50 nm (1000-2000 nm), 100 nm (2000-2500 nm)

² 1 nm (400-630nm), 2 nm (630-869 nm), 5 nm (869-1248 nm)

³ 1 nm (400-630nm), 2 nm (630-999 nm), 5 nm (999-2002 nm), 10 nm (2002-2500 nm)

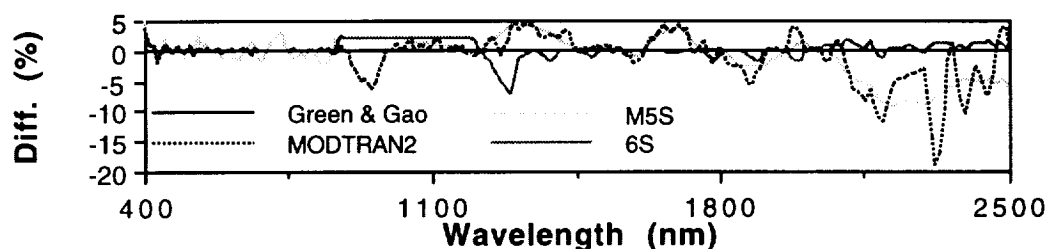


Figure 1: Percent differences between the exo-atmospheric solar irradiance (E_0) spectra with respect to the Green and Gao E_0 spectrum. The irradiance data sets were convolved to the AVIRIS bands.

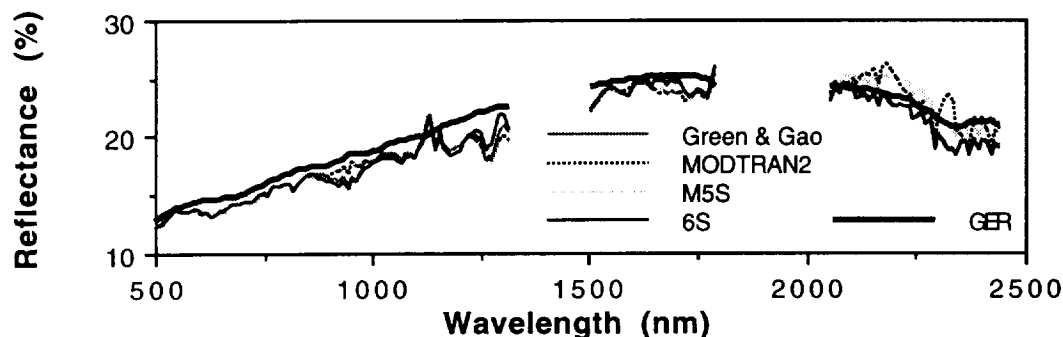


Figure 2: Surface reflectances of asphalt retrieved from AVIRIS data with MODTRAN2 using different solar irradiance functions, and the corresponding ground-based reflectance (GER). The atmospheric conditions used in the retrieval were: water vapour = 1.5 g/cm^2 ; aerosol optical depth at $550 \text{ nm} = 0.121$.

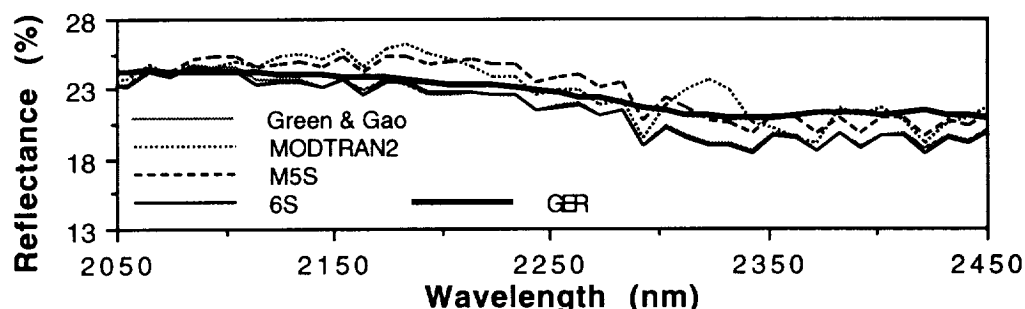


Figure 3: Surface reflectances of asphalt in the 2050-2450 nm region (Blow-up of Figure 2).

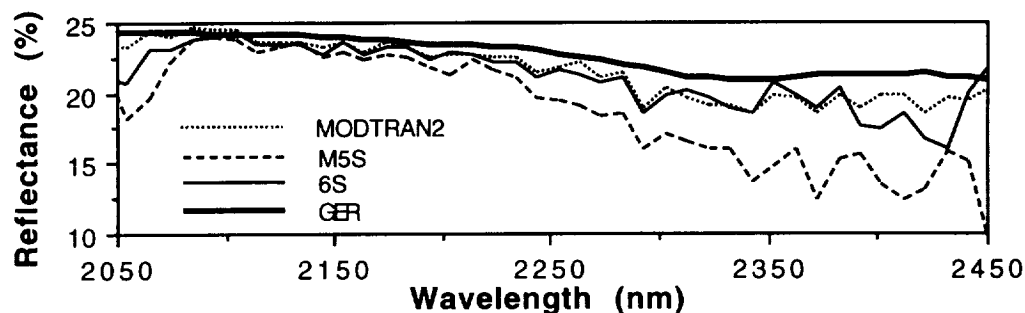


Figure 4: Surface reflectances of asphalt retrieved from the AVIRIS data with the different radiative transfer codes using the solar irradiance function proposed by Green and Gao as well as the corresponding ground-based reflectance (GER). The models were run with the same atmospheric conditions as those noted in Figure 2.